Calibration of HCAL

Calibration is measurement of
(ADC count/GeV)/(source gain)
The electronics should be final electronics.
The gains HPD should be close to their final value.
The testbeam calorimeter should match the geometry of
collision hall calorimeter, although they do not have to be
the same wedges.

Source gains

- Lab 5 - collimated source scan for each tower and layer
  i - $Col_{Lab5}(i)$
  Gain measured by wire source - $Wire_{Lab5}(i)$

- $Col_{Lab5}(i)$ and $Wire_{Lab5}(i)$ use the same PMT.

- At the testbeam after calorimeter is cabled up,
  we will meaure the wire source for each layer of a tower.
  $Wire_{testbeam}(i)$

- the true gain of a tile at the testbeam is
  $Gain_{testbeam}(i) = (Col_{Lab5}(i)/Wire_{Lab5}(i))*Wire_{testbeam}(i)$

- The true gain of a tile in the collision hall is
  $Gain_{coll_hall}(i) = (Col_{Lab5}(i)/Wire_{Lab5}(i))*Wire_{coll\_hall}(i)$
  where $Wire_{coll\_hall}(i)$ is the measured wire source in the
  collision hall.
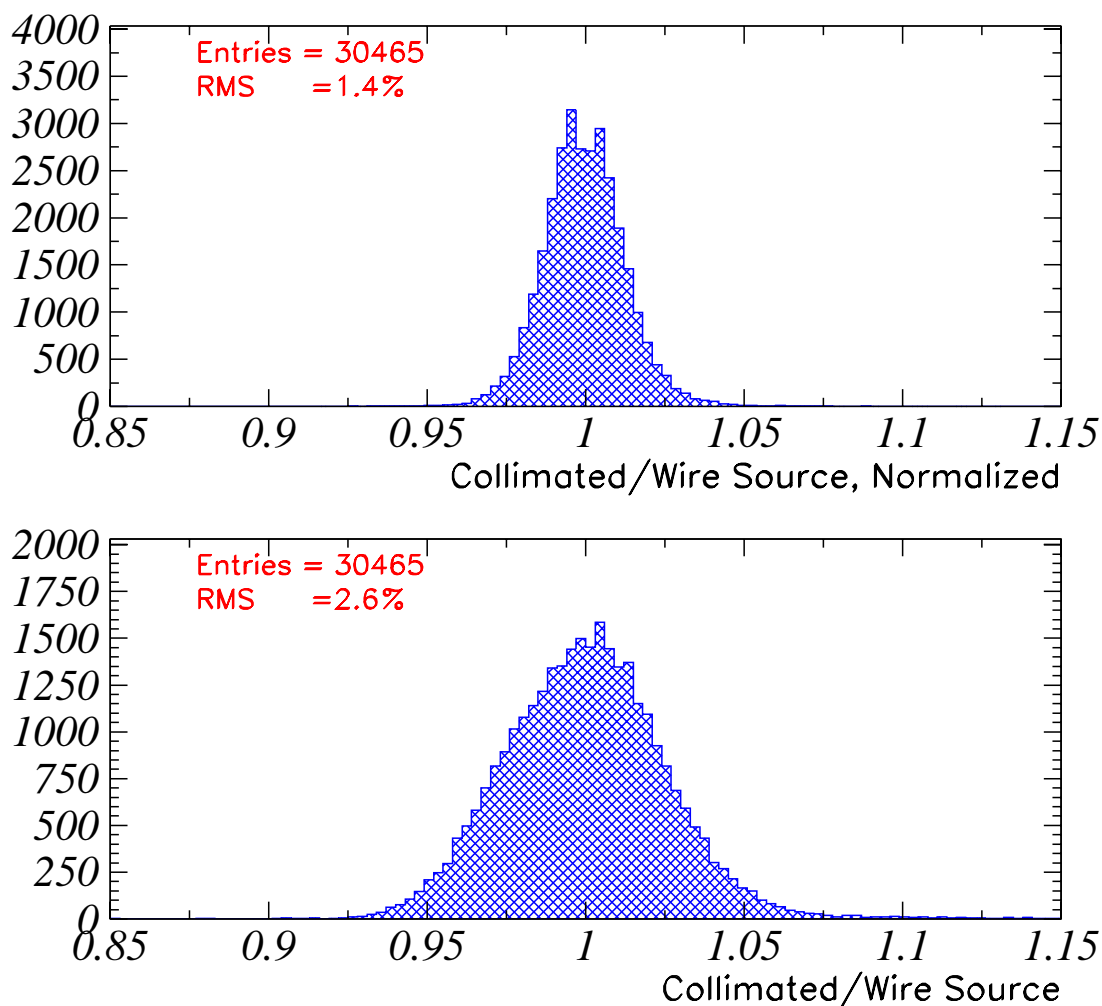
- Top plot is a histogram of the $\text{Col}_{Lab5}(i)/\text{Wire}_{Lab5}(i)$ for all tiles in HCAL. Each tower,layer is normalized to 1.0. Since the RMS of this plot is 1.4% the factor $\text{Col}_{Lab5}(i)/\text{Wire}_{Lab5}(i)$ can be the same for all the tiles in a particular tower,layer.

- The bottom plot is $\text{Col}_{Lab5}(i)/\text{Wire}_{Lab5}(i)$ with only one number to center the histogram on 1.0. The rms is still good, but the edge tiles are off the peak. Hence, one need one number for each tower, layer.

- The source gain of a tower in the testbeam (or for instance the collision hall)

$$\sum_{All\ Layers\ i} Gain_{testbeam}(i) * Shower\_weight(i) \quad (1)$$

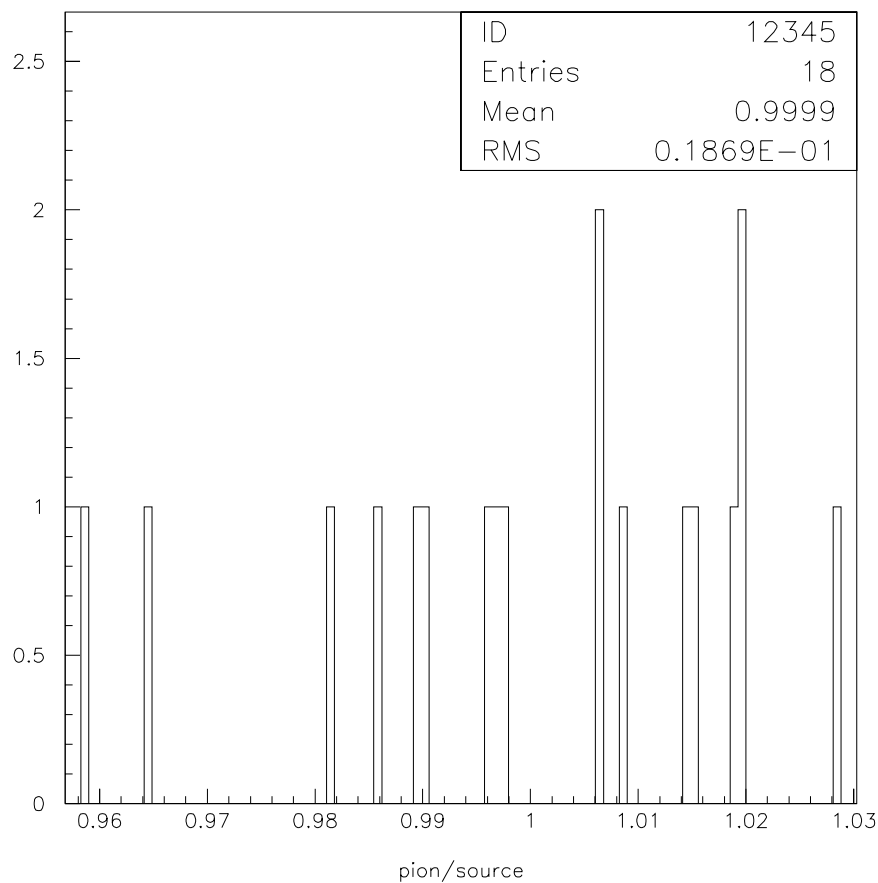 where $Shower\_weight(i)$ is a hadron shower profile vs layer i.

- This gives the source gain for hadrons.

- The $Shower\_weight(i)$ can be flat vs i, in which case the shower gain is for muons.

Beam gain and calibration constant C_{tower}

- Pick some energy and use that for the calibration CDF used 57 GeV.

- Measure ADC count/GeV for testbeam.

- We can measure our calibration constant C_{tower}

- $C_{tower} = (\text{ADC count/GeV})/(\text{source gain})$

- We measure this for a variety of tower, it should be similar for all towers.

- As long as the electronics and timing are the same for the collision hall and testbeam the calibration constant is the same.

ID   11
Entries   48
Mean   0.9963
RMS   0.1311E−01
UDFLW 0.0000E+00
OVFLW 0.0000E+00

RMS/Mean = 1.3%
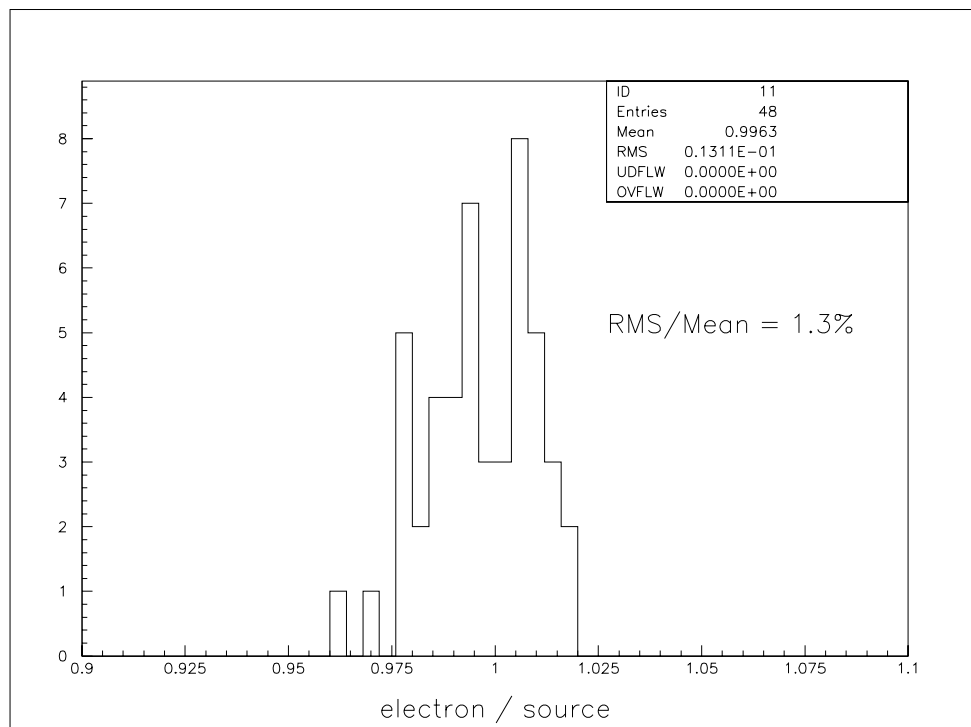
electron / source

CDF EM calorimeter - electrons/source

ID   12345
Entries   18
Mean   0.9999
RMS   0.1869E−01

pion/source

CDF Hadron calorimeter - hadrons/source

Calibration tests at the testbeam

– This should be done for many towers and the value histogramed.

– This can also be done with muons, with equal weighting.

– The time stability of the calibration constant should be measured.

  * Pick a control tower.
  * Periodically measure this control tower.
  * At same time measure with the laser.
  * Run the single layer source .
  * The laser, source, and beam should track each other.

Problems in the calibration

- Differences between the testbeam and collision hall create problems in calibration.
- Electronics for source measurement
  * Source measurement is 0.5 ADC counts.
  * The spec for the differential nonlinearity of the ADC in a count is 0.01.
    This is due to variation in the size of the first couple ADC bins.
  * Hence, the electronics for the source measurement could contribute 2% to a histogram of the calibration constants in the testbeam
  * Measurements are being done to determine what it is.
  * If the testbeam electronics has exactly the same differential nonlinearity as the collision hall electronics then the error on the calibration will be smaller.
  * In addition the beam and the source are on different ranges. One needs to know those offset and gains of those ratios to .5%

- ODU cross talk from optical and magnetic effects
  * In principle the cross talk effects the source and beam the same way.
  * However, the source measurement is the gain measurement for the tower we have the source on. Some of the light from the source gets put into other towers and gets ignored.
  * However, for the beam we are doing a sum over towers. For beam, cross talk light get put in other towers. If these towers are not in the sum we are fine. But if these towers are in the sum, we are not doing the same thing for the source. Hence, we get an error in the calibration vs source. This may mean the calibration is eta dependent. This effect could be removed by understanding the ODU.
  * Note there will still be a residual error due to the random placement of the fibers in the each hole of the ODU.
  * For the cross talk from the magnetic field this gives an error in the calibration.
  * This could be 2% effect for a 3 by 3 sum or more in a 5 by 5 sum.
  * This can be understood by mapping out the ODU and doing event by event correction in the test-beam data.
  * Magnetic ODU design put about 2.1 T at the HPD.

∗ According to Minn plots this reduces the cross talk by about a factor of 2.

● Magnetic field on calorimeter in collision hall

– Scintillator brightning, run source with magnetic field on should correct the effect.
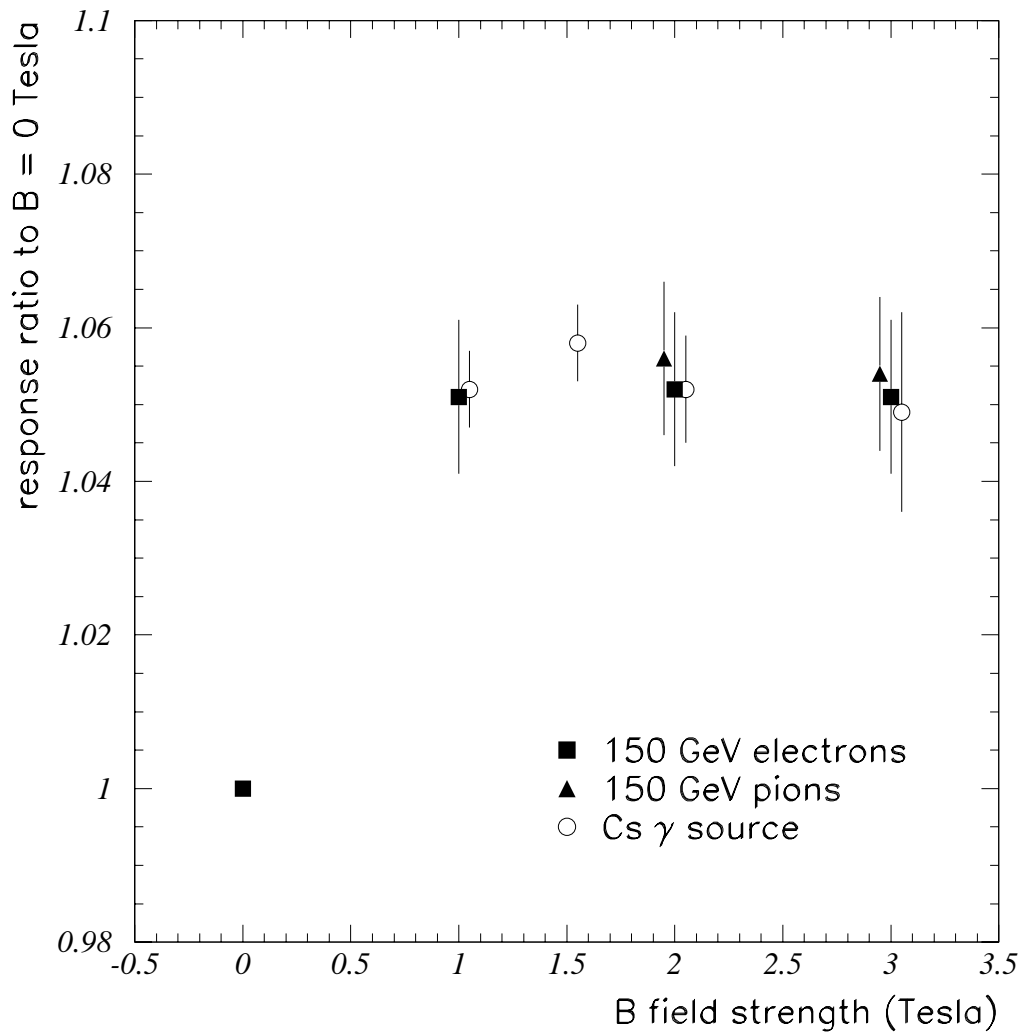
– With Barrel additional effect due to curvature effect
of electrons in magnetic field, geometric effect.
Additional 10% effect to HCAL.
But with energy in EM calorimeter effect$\sim$ 5%.
Not clear what is the error on this 5%.
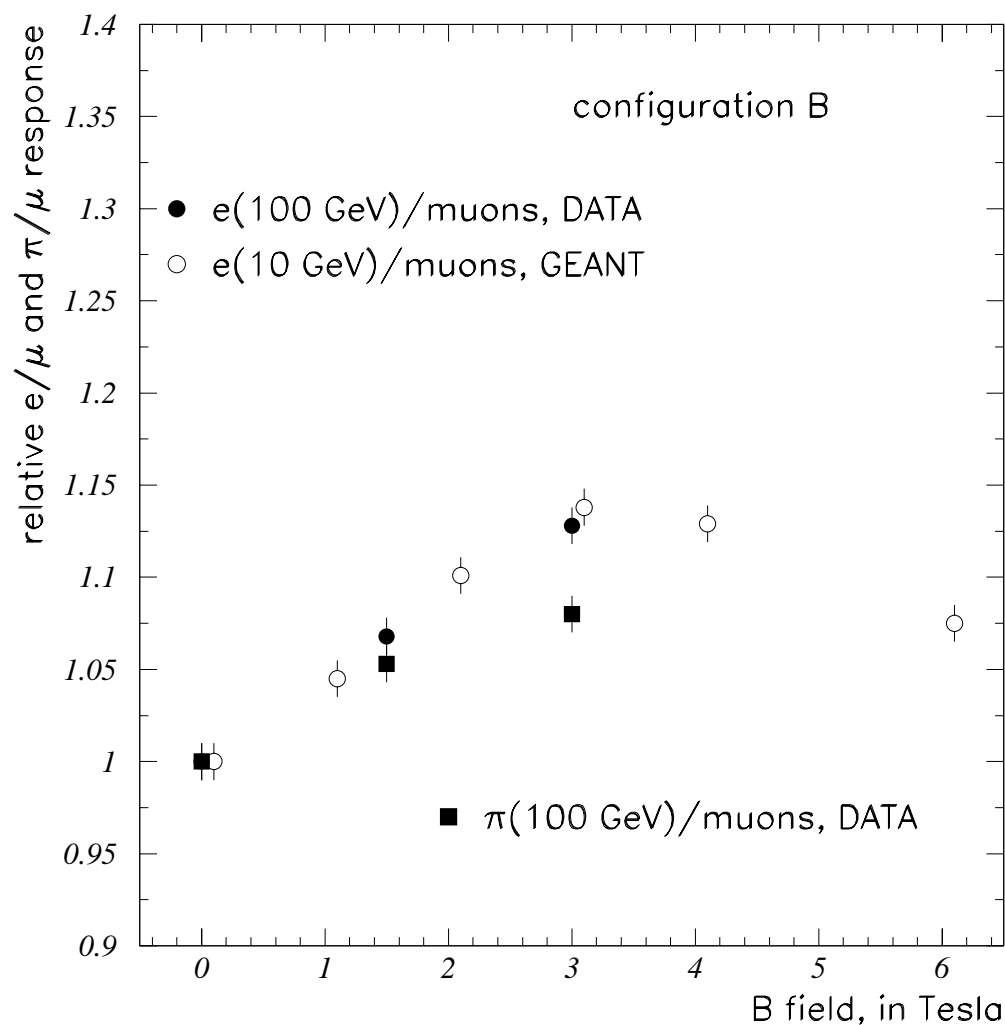
Collision Hall - Calibration is for Jets

- Convulute fragmentation functions with the response of a hadron or photon (for π^0)

- Need to understand the linearity of calorimeter down to as low an energy as possible.

- Need to do this since calorimeter is not linear.

- CDF does this with minimum bias data, but there is no testbeam data to compare it with. But you want isolated hadrons, Will they exist in LHC?

CDF calibration for Central, from Rick Vidal

- Base line calibration established using 50 GeV hadrons with MIP in the EM.

- Gains of tubes are equalized using the source.

- The radioactive sources were then used to track the calibration.

- Get jet scale for Run 0

  - "minimum bias" events (Pt < 5 GeV)
  - a single stiff track trigger (5-10 GeV),
  - low energy test beam data (P > 10 GeV).
  - Isolated tracks in the CTC were used for the collision data.
  - Luminsoity was low so only background was π^0.
  - No background from multiple interactions.
  - To estimate this background, we used the border towers around the 3x3 hadron (plus 1 EM) .
  - A Monte Carlo correction was found that gave the correct jet energy from the "measured" energy deposited in the CDF EM and hadron calorimeters.
  - A correction to get the parton-level energy including out-of-cone corrections, b-quark correction, etc.
  - The calibration could not be checked by looking at γ + jet, or jet-jet balancing.

- Get jet scale energy scale for Run 1.

  - The same procedure was followed, except that a lower-Pt single particle trigger was developed.

  - Multiple interaction per crossing created an additional background from π^0 coming from the "underlying event".

  - an average correction was implemented, since the luminosity was always within a limited range.

  - This time, the much better statistics allowed the π^0 background to be estimated using tracks that are minimum ionizing in the EM tower, and then looking at the EM energy in the surrounding towers.

  - When the inclusive jet cross-section for Run 1 was compared to Run 0, it was about 10% lower than that measured in Run 0 (1% energy scale causes 5% shift in the cross section).

  - The source of this discrepancy was never discovered.

  - An additional correction was applied to the Run 1 data to fix this problem.

  - With more statistics, both γ + jet and jet-jet balancing were used to check the final jet-energy calibration. The agreement was satisfactory in Run I.

In Situ Calibrations, from J. Freeman and W. Wu They give two processes

- Z + Jet Analysis

  – CDF concludes they can do calibration to 5%.

  – In one month of running you get 0.7M events.

  – Useful for calibration, but Freeman does not give an error on calibration.

- W $\rightarrow$ Jets in $t\bar{t}$ events.

  – with $t, \bar{t} \rightarrow$ W + b
    One W decay semileptonically
    Tag both b Jets
    Reconstruct W $\rightarrow$ 2 jets

  – CDF 8 events with σ/mean about 10%.

  – 1 month of running 45,000 double tagged events.

  – Freeman does not give an error on calibration.

- Muons

  – Freeman claims this is not very useful.

  – 1 GeV deposited on calorimeter while interesting scales are at multi-100 GeV.

  – Will be contaminated by Min-bias.
    At η=0 for 30 min bias events it is 30 MeV with a long tail.